Ministry
of the
Environment

Water Investigations
Report 16

TEMPORAL VARIATION OF SOUTHWESTERN ONTARIO STREAMFLOWS and the possible influence of Agricultural Land Drainage

Water Resources Paper 15

TEMPORAL VARIATION OF SOUTHWESTERN ONTARIO STREAMFLOWS

and the Possible Influence of Agricultural Land Drainage

by

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Toronto, Ontario
1982

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ISSN 0708-4749
ISBN 0-7743-7283-4

Parts of this publication may be quoted if credit is given. It is recommended that reference to this report be made in the following form:

Eddie, J.D., 1981. Temporal Variation of Southwestern Ontario Streamflows and the Possible Influence of Agricultural Land Drainage.

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ABSTRACT

Temporal variation of streamflows in southwestern Ontario was examined over a 30-year period (1950-1979). Changes in flow regime were sought which might be attributed to the effects of agricultural land drainage.

Annual mean, annual maximum, and annual minimum daily streamflows for five representative long-term stations failed to exhibit any discernible consistent trends, fluctuating instead about the period mean in a reflection of annual precipitation patterns. Five stations located in smaller basins, and more likely to reflect the impact of agricultural drainage, showed similar results for the longest common period of record available (1967 to 1979).

ACKNOWLEDGEMENTS

The study was carried out under the general supervision of Mr. D. Terry and Mr. Ulo Sibul of the Hydrology and Monitoring Section, whose comments and editorial assistance are gratefully acknowledged. The assistance by staff of the Technical Support Section of the Southwestern Region of the Ministry also proved valuable during the course of this study.

Introduction

The high intensity of agriculture in southwestern Ontario has resulted in the widespread use of underdrain systems and in ditching and ditch clean-outs to facilitate drainage. The benefits of land drainage in the agricultural community are well-documented, and include improvements to soil physical properties, earlier dates of planting and timeliness with all farm operations, more efficient machine use, and improved crop quality and yields. Little emphasis however, has been given until recently to the possible broader impacts of agricultural land drainage.

In the last decade there has been an explosion of interest in man's relationship to his environment, and greater attention has come to focus on some of the environmental consequences of land drainage. Given that land drainage works are built to alter the natural distribution of water in space and time, it is to be expected that land drainage activities will have implications for the modification of the hydrologic regime of an area. With respect to streamflows, two important questions related to the possible effects of land drainage are:

1. Does land drainage significantly increase peak flows in streams downstream of drainage works?

2. Does land drainage reduce dry weather flows downstream of drainage works?

The impact of individual drain construction or clean-out on streamflow may be small. The cumulative effect of several surface drains and associated tile drainage systems within a drainage basin may, however, affect the magnitude of both peak flow and dry weather flow rates. Given the widespread application of agricultural land drainage throughout southwestern Ontario, one might expect to recognize these changes within the historic daily streamflow record.

This paper deals with the temporal variation of flows over 30 years of historic streamflow record in southwestern Ontario. While the primary interest is with the possible influence of agricultural land drainage, it is recognized that there are other potential causes for temporal changes in streamflows, including climatic factors and changing land use. Although other causative factors are considered in passing, they are not investigated in detail.

The hydrologic investigation is based on analyses of annual means, annual maximum daily, and annual minimum daily streamflows, each expressed as a ratio of their corresponding long-term (30 years) mean. The ratios derived for five representative long-term stations are used as a basis for examining the temporal and regional variability of streamflows in southwestern Ontario. Similar ratios, derived for five short-term (13 years) stations with a high proportion of agricultural land drainage works within their watersheds, are then examined for deviations from the "normal" variabilities shown by the long-term stations.

Station Selection

In southwestern Ontario most of the major land drainage projects date from before World War II, while continuous monitoring of streamflows by the Water Survey of Canada on a regional scale did not begin until the late 1940s, and was intensified only in the mid-1960s. Many drainage projects in the post-1950s period have involved reconstruction of existing drains, rather than the new drainage of large areas of land.

The streamflow data for this study were taken from the records collected and published by the Water Survey of Canada of the Inland Waters Directorate, Canada Department of the Environment. The streamflow stations used are listed in Table 1, and their locations are shown on Figure 1. Included in the table are periods of record, drainage areas above the gauges, and an indication of the dominant soils drained.

Several hydrologic regimes (as indicated by topography and soils for purposes of this report) are represented by the selected streams. The long-term stations provide regional coverage of streamflows originating from both the generally flat, clay soils in Huron, Perth, and Middlesex counties in the south and from the more hilly topography and medium and coarse-textured soils in Bruce and Grey counties to the north. As well, because the drainage areas above these stations are generally large (greater than 700 km^2) and include a broad range of agricultural land uses, the records at these stations present a good overview of general streamflow conditions in southwestern Ontario.

The short-term stations were selected to examine recent streamflows in small sub-basins within the larger drainage basins mentioned above. As such, the short-term stations include the same variety of soils, but because of the smaller basin sizes, they are more likely to reflect the impact of changes resulting from changing agricultural land use and land drainage.

Data Analysis

The long-term streamflow regime in southwestern Ontario was assumed to be represented by the 30-year reference period 1950-1979. Thirty years of record is the maximum that could be used, dictated by the necessity to include a reasonable number of streams for regional representation. This period is a useful standard, but has no particular hydrological significance and it does not necessarily occupy a noteworthy position in a climatic cycle. It is however, considered representative of most recent activities in the drainage of agricultural lands.

From the stations in the study area with 30 years of record, five stations that were known to be free of significant diversions or regulations by dams were selected for detailed analysis. For each station, the mean flow for the 30 years of record was calculated and each annual value within the period was expressed as a ratio of this long-term average. The variation of each year's flows about the long-term mean was then evident. The 5-year moving average of these ratios was then computed to smooth the short-term variations and assess temporal trends. The above calculations were performed for the annual means, annual maximum daily and annual minimum daily flows for each station, and the results plotted on rectangular graph paper.

In order to more fully assess the streamflow character of the area, a second group of stations with drainage areas less than 500 km^2 was considered next. These stations were known to have a high percentage of their watershed area under drainage and therefore might be expected to differ from the long-term stations. The record available for this group of stations was limited, however, to the 1967-1979 period. For this group of stations the mean for the 13-year period was used as the average and the analysis previously performed for the long-term stations was repeated.

In the analysis of minimum daily values for the smaller watersheds, a considerable number of zero values were encountered and the ratios derived from these values are not meaningful. In such cases, minimum monthly values were substituted.

A graphical approach was used for the final overall assessment. The 5-year moving average plots of the mean annual, annual maximum daily, and annual minimum daily flows for each of the individual long-term stations were assembled on a common axis. This was repeated for the short-term stations. The simplicity of this graphical approach affords maximum opportunity to exercise judgment in the interpretation of the data.

Trend Analysis At Long-Term Stations

Figures 2 to 4 are composite plots of 5-year moving averages developed in the study to visually examine both the temporal and regional variability of streamflows at the long-term stations in southwestern Ontario. The pattern formed for each station gives a visual indication of both long and short-term temporal trends. The pattern similarity among stations and the close grouping of curves in turn give a measure of the homogeneity of streamflows over the entire study area.

Figure 2 illustrates the ratios of the annual mean discharges to the long-term mean for the 1950 to 1979 period. Looking at this 30-year period, no pronounced overall upward or downward trend is observed, but rather the annual mean flows fluctuate in a cyclic pattern about the mean. In comparing the 5-year moving average curve of total annual precipitation to the streamflow curves, it can be seen that the streamflow curves are similar to that of the precipitation, indicating a high measure of climatic influence on the annual streamflows. The cycles are interesting in that the drought period of the mid-1960s, a well-remembered time in southwestern Ontario, shows clearly as the lowest point in the record. Wet years in the late 1960s resulted in a fairly rapid return to the levels observed in the early 1950s. The 1970s are characterized by a minor upward trend with slightly below average levels in the early years of the decade, followed by a return to the high levels observed in the late 1960s. The curve patterns for all stations are remarkably similar in shape, suggesting a high measure of climatic and hydrologic homogeneity on an annual basis over the area.

Figure 3 provides curves of the ratios of the of maximum daily discharge to the long-term mean for the 1950-1979 period, expressed as a 5-year moving average.

Again the same cyclic pattern of fluctuations about the mean is seen, although the range from highs to lows is not as great. The impact of the mid-1960s drought is not as pronounced here, but the rise to above average levels in the late 1960s and the upward trend in the 1970s can be observed. Looking at the entire 30-year period, there is no overall upward or downward trend observed in the maximum daily flows.

While the curves for all stations show the same pattern of cyclic rise and fall, some clearly fluctuate over a greater range than others. This difference in variability can probably be attributed to differences in the basin characteristics of topography and soil. The Sydenham River near Alvinston, and the Maitland and Ausable rivers, all of which drain flat, less permeable, fine-grained soil areas are more variable than the Saugeen River and Sydenham River near Owen Sound, which flow from more permeable, coarse-textured soil areas to the north.

Figure 4 illustrates the ratios of the annual minimum daily discharge to the long-term mean for the 1950-79 period, expressed as a 5-year moving average. While it can be seen that the minimum daily flows fluctuate in a cyclic pattern about the mean, the patterns are more inconsistent. At three of the stations - the Saugeen River near Port Elgin, Ausable River near Springbank and Sydenham River near Alvinston, the minimum daily flows show a response similar to that shown by the mean annual flows in Figure 2, with no overall upward or downward trend over the 30-year period. In contrast to this, the curves for the Sydenham River near Owen Sound and the Maitland River near Donnybrook have a distinct upward slope, reflecting an increase in the minimum daily flows over the 30-year period.

Trend Analysis at Short-Term Stations

Figures 5 to 7 are composite plots of 5-year moving averages developed to visually examine the temporal and regional variability of streamflows at the short-term stations.

Figure 5 provides curves of the ratios of the annual mean discharges to the 1967-1979 mean for the short-term stations. Although more difficult to assess because of the comparatively short period of record, a cyclic pattern of fluctuations about the mean is again evident. A comparison of the curve patterns in Figure 5 with those of Figure 2 (mean annual discharges for the 1950-1979 period) indicates similar temporal and regional variability for both groups.

Figure 6 provides curves of the ratios of annual maximum daily discharge to the 1967-1979 mean for the short-term stations. A comparison of the curves in Figure 6 with those in Figure 3 indicates that the pattern exhibited in the maximum daily flows at the short-term stations during the 1970s is generally similar to that of the 1967-79 portion of the long-term stations. While an upward trend in the maximum daily flows for the late 1970s is observed in the curves of Figure 6, comparison with the curve patterns in Figure 3 suggests that the apparent trend may just be part of a broader pattern.

Figure 7 illustrates the ratios of annual minimum daily discharges to the 1967 to 1979 mean for the short-term stations. Analysis of minimum flows for the smaller watersheds of some of the short-term stations included a considerable number of zero values. The ratios derived from zero values were not meaningful and minimum monthly values were substituted in such situations. A curve was not derived for South Parkhill Creek as zero values appeared in the monthly record as well.

The extreme variation in dry weather flows is evident, although some similarity of curve patterns during the 1970s between the long-term and some short-term stations is evident. The minimum daily flow

curve pattern for the station on the Bayfield River near Varna is noticeably different, showing a pronounced downward trend over the period 1972 to 1979. A slight downward trend since 1972 for Carrick Creek can also be observed.

Summary and Conclusions

The curves of annual mean and annual maximum daily flows for the long-term streamflow stations in southwestern Ontario for the 1950-1979 period show that flows have fluctuated about the mean in a cyclic pattern, which appears primarily to be a reflection of climatic conditions. Looking at the entire 30-year period, there is no apparent overall upward or downward trend. The curves for all stations are remarkably consistent, evidence of similar hydrologic response throughout the area.

The curves of annual minimum daily flows for the long-term streamflow stations also show flows fluctuating about the mean in a cyclic pattern. While some upward and downward trends can be observed during the 30 years, the pattern consistency from station to station is much less evident. At three stations - Saugeen River, Ausable River and Sydenham River, no overall upward or downward trend over the 30-year period is evident. This is contrasted by the Sydenham River near Owen Sound and the Maitland River near Donnybrook which show a distinct upward trend in the minimum daily flows over the 30-year period.

The curves of annual mean and annual maximum daily flows for the short-term stations in southwestern Ontario, although difficult to assess because of the comparatively short period of record, appear to show a response nearly identical to that of the long-term stations.

The curves of annual minimum daily flows for the short-term stations may be of questionable value in assessing flow variability because a considerable number of zero values in the daily and even monthly mean records prevented uniform analysis at all stations. On the

four stations for which analyses were possible, the Bayfield River near Varna shows a distinct downward trend in the annual minimum daily flows over the entire period 1972 to 1979, with a smaller downward trend since 1972 on Carrick Creek.

From the above observations it is generally evident that the analysis of annual mean and annual maximum daily streamflows in southwestern Ontario do not show changes on an annual basis for areas of intense agricultural land use. There may however, be localized effects which have not shown up in this analysis. The observed upward trend of minimum daily flows over the past 30 years at the Sydenham River near Owen Sound and the Maitland River near Donnybrook, and the downward trend of minimum daily flows over the past 13 years at the Bayfield River near Varna, and possibly on Carrick Creek, require further investigation. A more intensive assessment of these basins involving a detailed inventory of agricultural land use and drainage and streamflow might provide the explanations for the observed trends.

On a more general scale, further investigations of streamflow data over shorter periods, as for example seasonal or even monthly flows, may indicate streamflow changes not evident from annual data analysis made in this report. An ultimate approach to the question of the effects of agricultural drainage on streamflows would involve the monitoring of streamflows and changing drainage conditions in selected watersheds in order to better understand the degree and sensitivity of streamflow responses to agricultural drainage.

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TABLE 1: STREAMFLOW STATIONS AND WATERSHED CHARACTERISTICS

Map No.	Stn No.	Station Name	Years of Record	Drainage Area km2	Dominant Soils & Drainage Characteristics
		LONG-TERM STATIONS			
1	02FA007	Sydenham River near Owen Sound	1949-79	181	medium textured soils formed on till, good drainage
2	02FC001	Saugeen River near Port Elgin	1916-79	3960	medium & coarse textured soils formed on coarse till, good drainage
3	02FE004	Maitland River near Donnybrook	1948-79	1760	medium & fine textured soils formed on fine till, good drainage
4	02FF002	Ausable River near Springbank	1948-79	865	fine textured soils formed on till or lacustrine sediments, fair drainage
5	02GG002	Sydenham River near Alvinston	1949-79	730	fine textured soils formed on till or lacustrine sediments, fair drainage
		SHORT-TERM STATIONS			
6	02FC011	Carrick Creek near Carlsruhe	1954-79	163	medium textured soils formed on till, good drainage
7	02FE003	M. Maitland River near Listowel	1954-79	77.7	medium textured soils formed on till, fair drainage
8	02FF007	Bayfield River near Varna	1967-79	466	fine textured soils formed on till, good drainage
9	02FF004	S. Parkhill Creek near Parkhill	1967-79	41.4	fine textured soils formed on till or lacustrine sediments, fair drainage
10	02GG006	Bear Creek near Petrolia	1967-79	267	very fine textured soils formed on lacustrine sediments, poor drainage

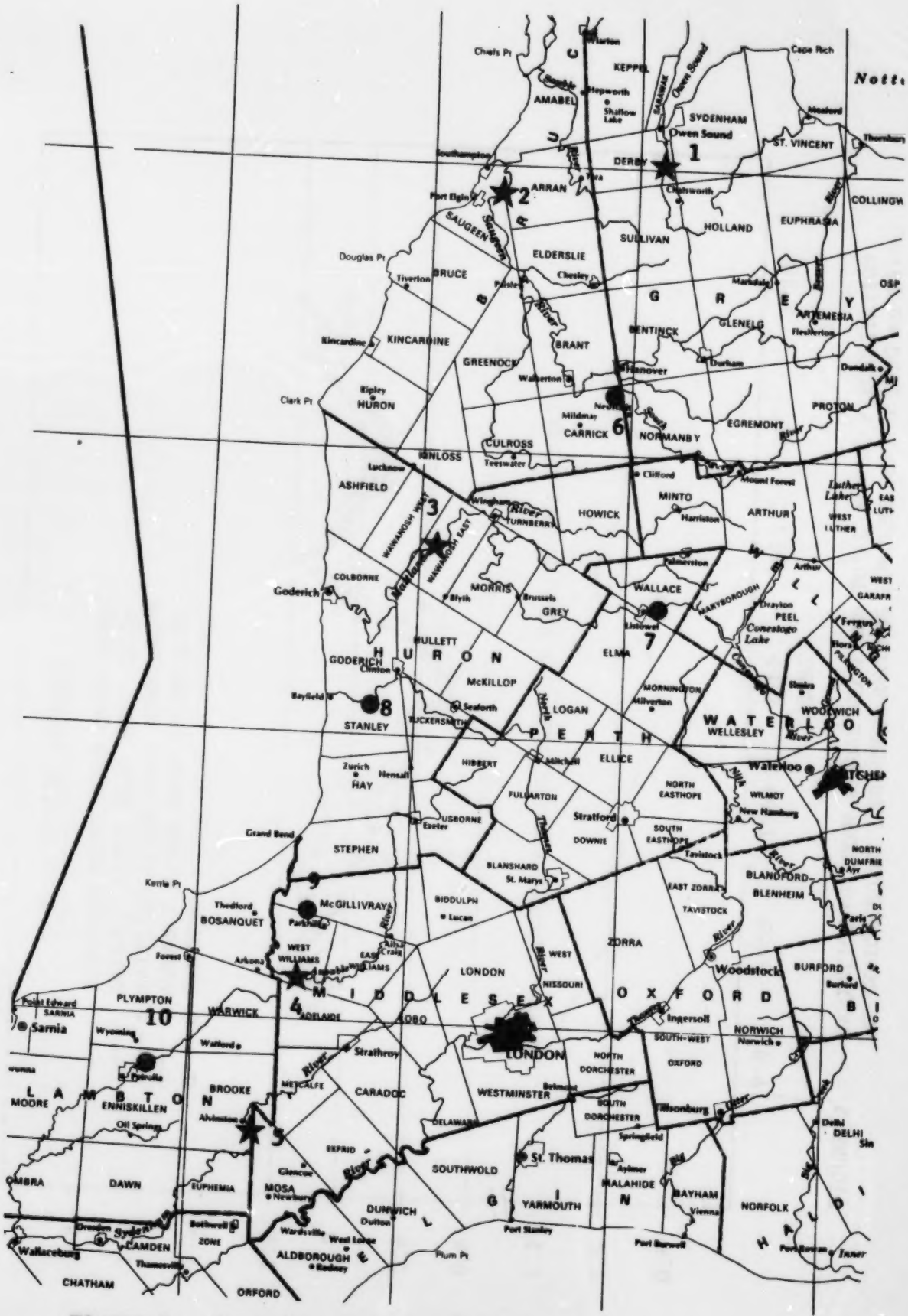

Figure 1. Location of Streamflow Stations

★ - Long-Term Station ● - Short-Term Station

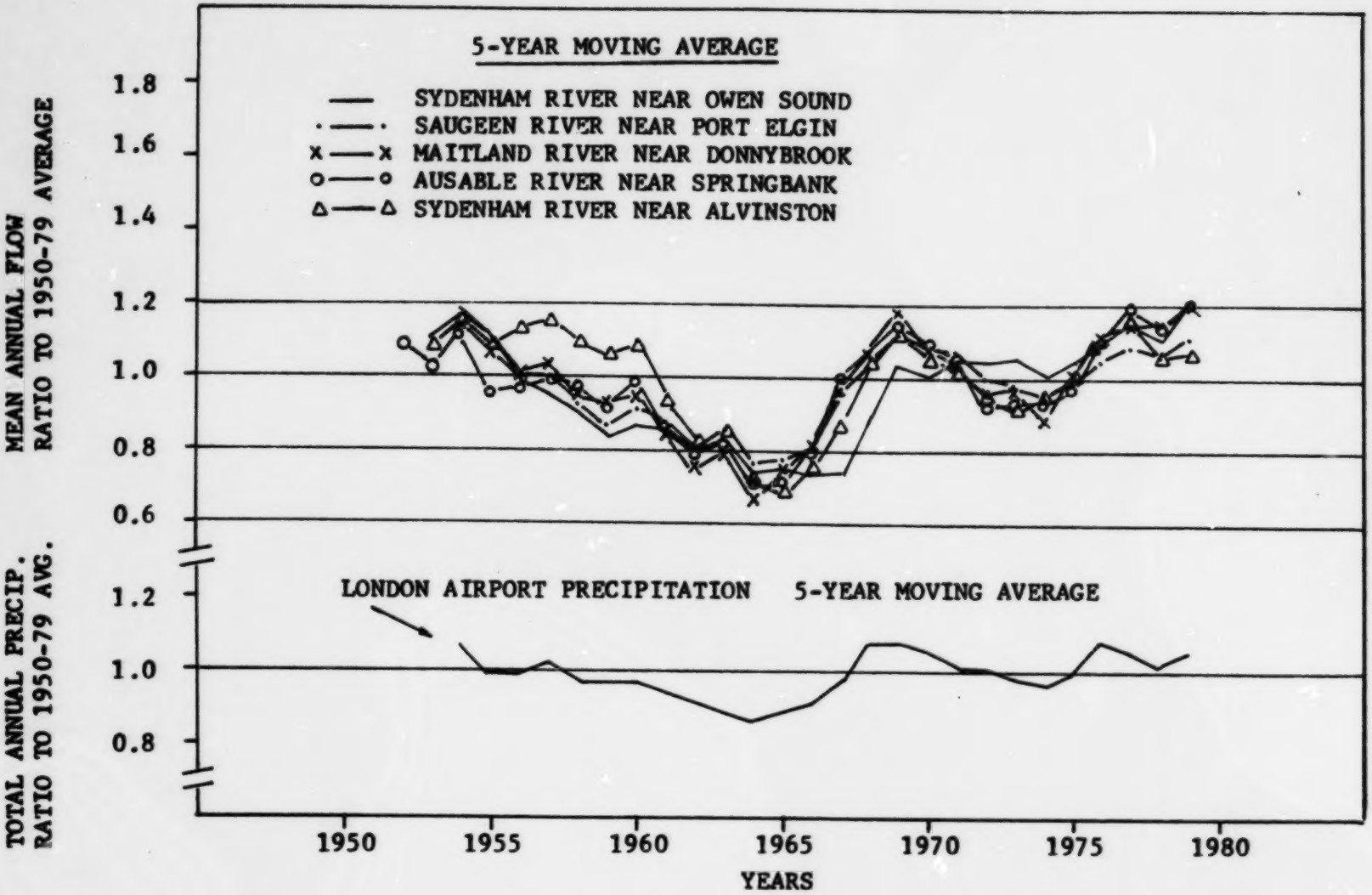

FIGURE 2. VARIATION OF MEAN ANNUAL FLOW AND TOTAL ANNUAL PRECIPITATION AS INDICATED BY LONG-TERM RECORDS FOR THE PERIOD 1950 to 1979.

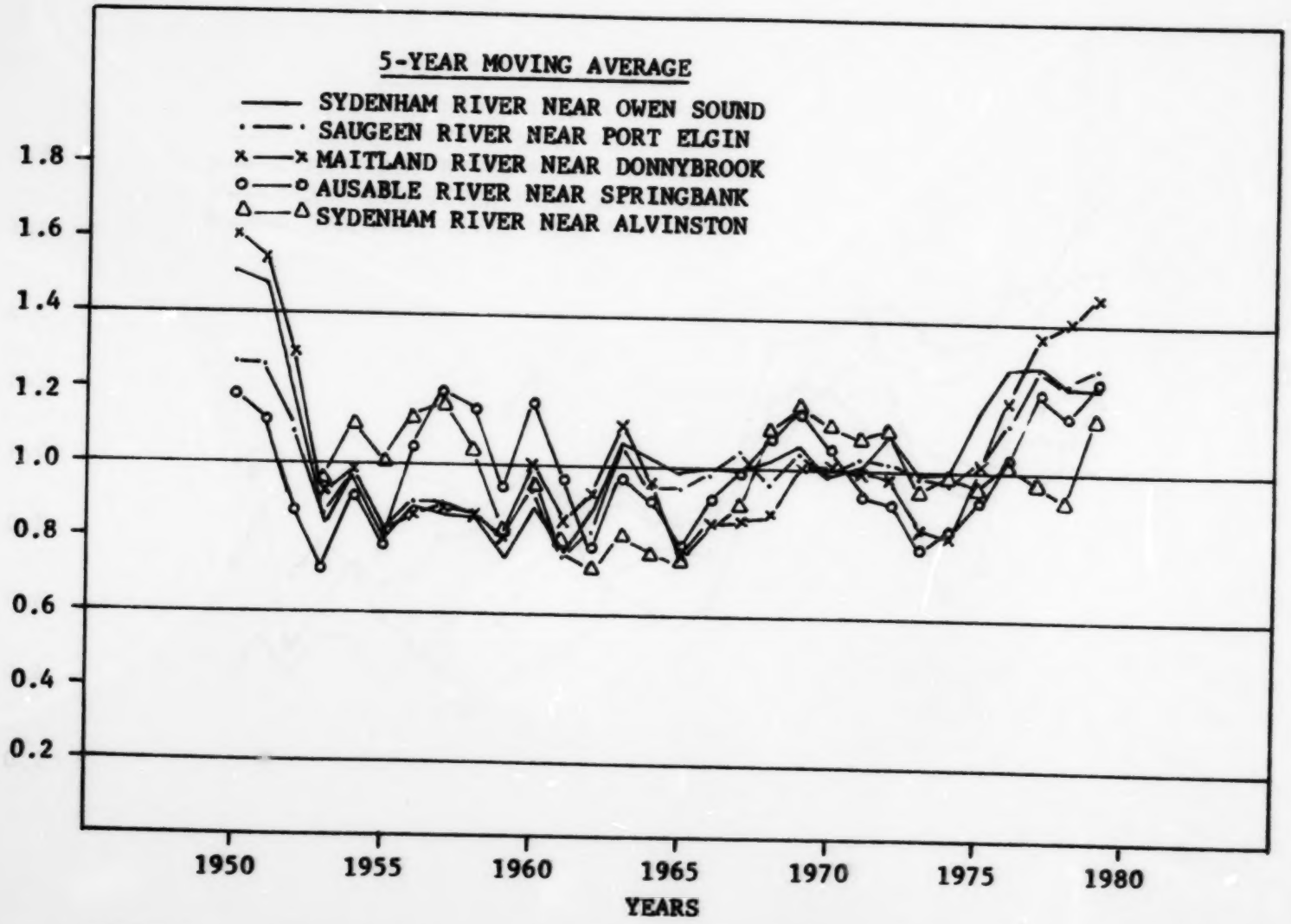

FIGURE 3. VARIATION OF ANNUAL MAXIMUM DAILY FLOW AS INDICATED BY LONG-TERM RECORDS FOR THE PERIOD 1950 to 1979.

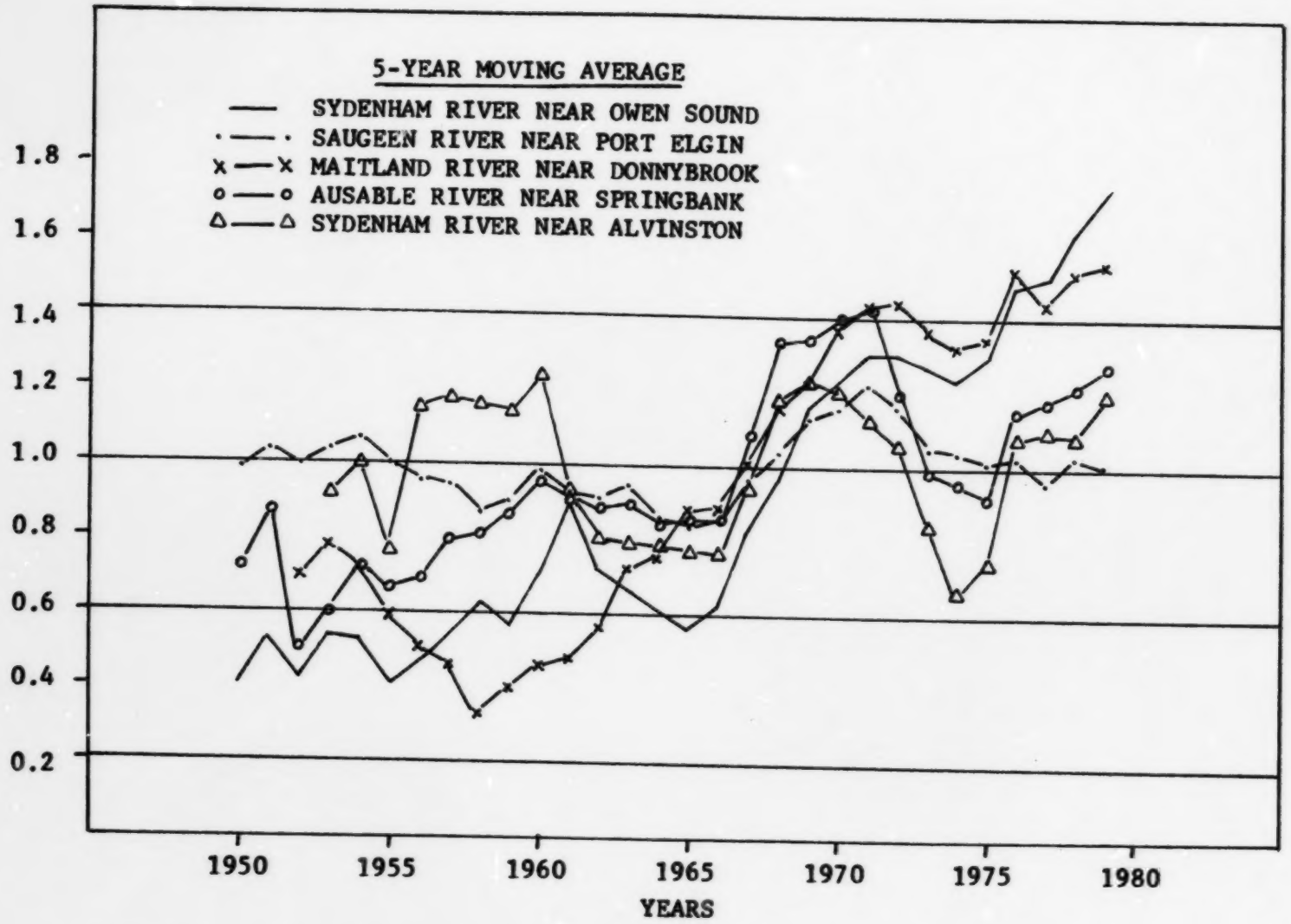

FIGURE 4. VARIATION OF ANNUAL MINIMUM DAILY FLOW AS INDICATED BY LONG-TERM RECORDS FOR THE PERIOD 1950 TO 1979.

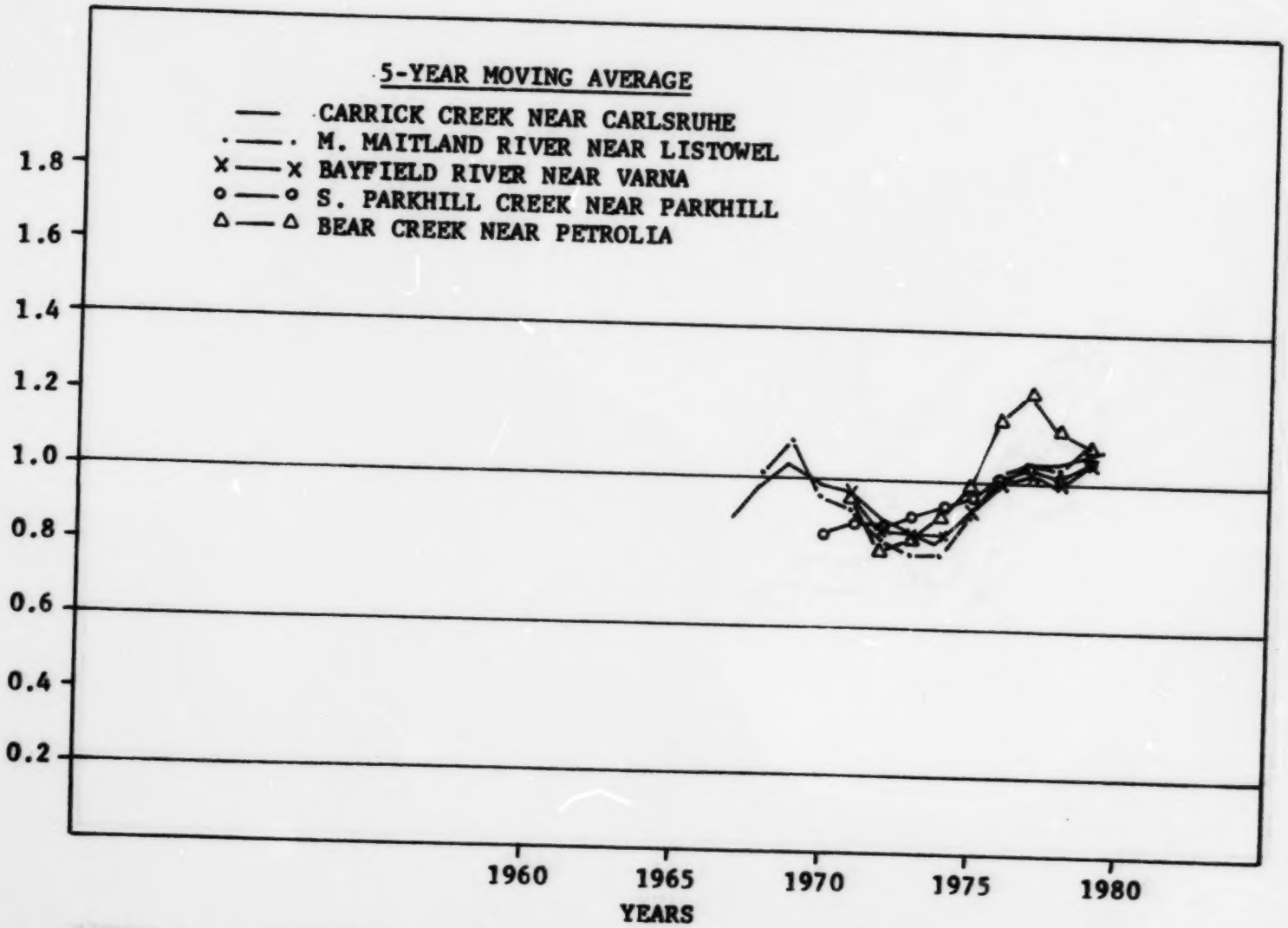

FIGURE 5. VARIATION OF MEAN ANNUAL FLOW AS INDICATED BY SHORT-TERM RECORDS FOR THE PERIOD 1967 to 1979.

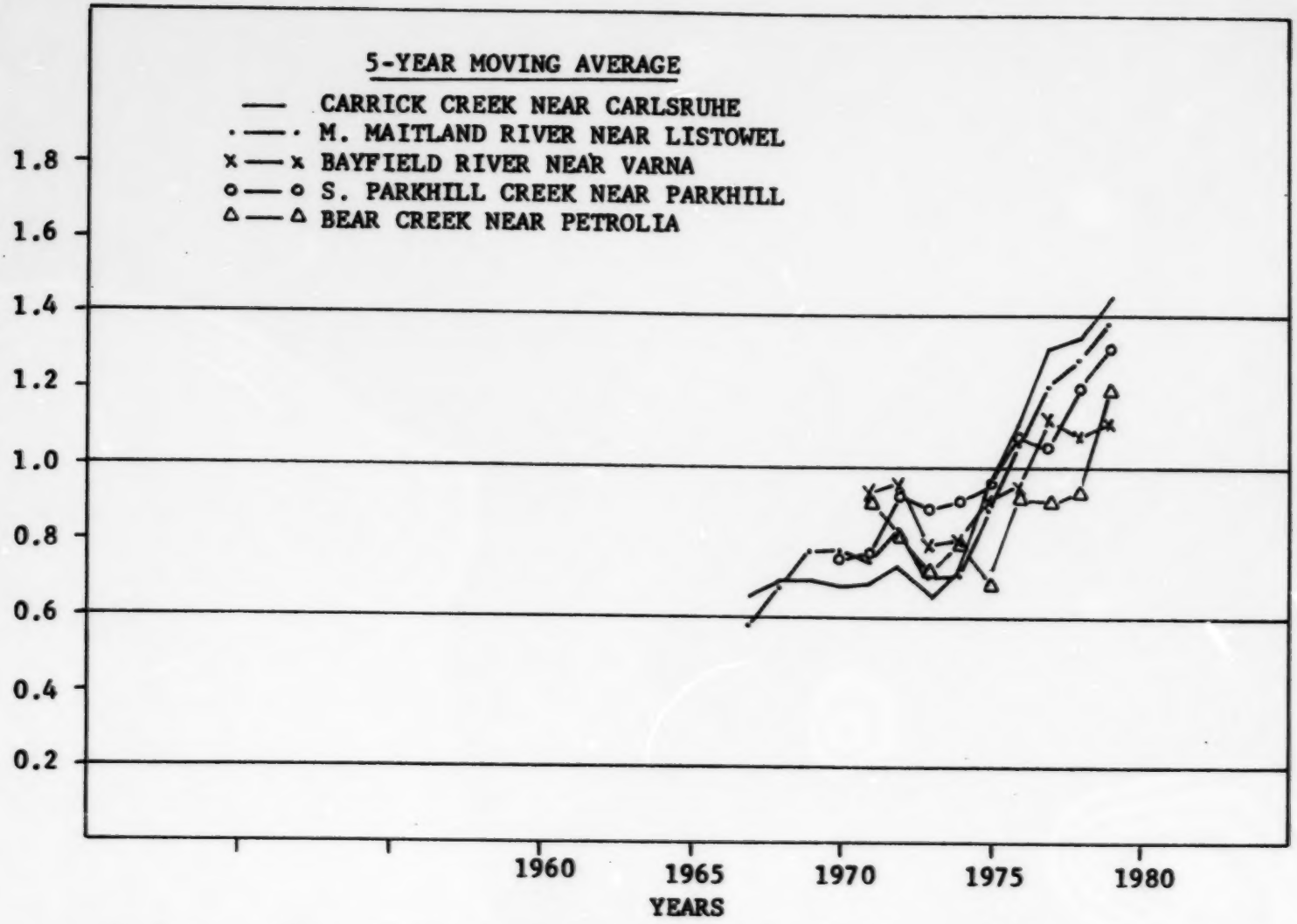

FIGURE 6. VARIATION OF ANNUAL MAXIMUM DAILY FLOW AS INDICATED BY SHORT-TERM RECORDS FOR THE PERIOD 1967 to 1979.

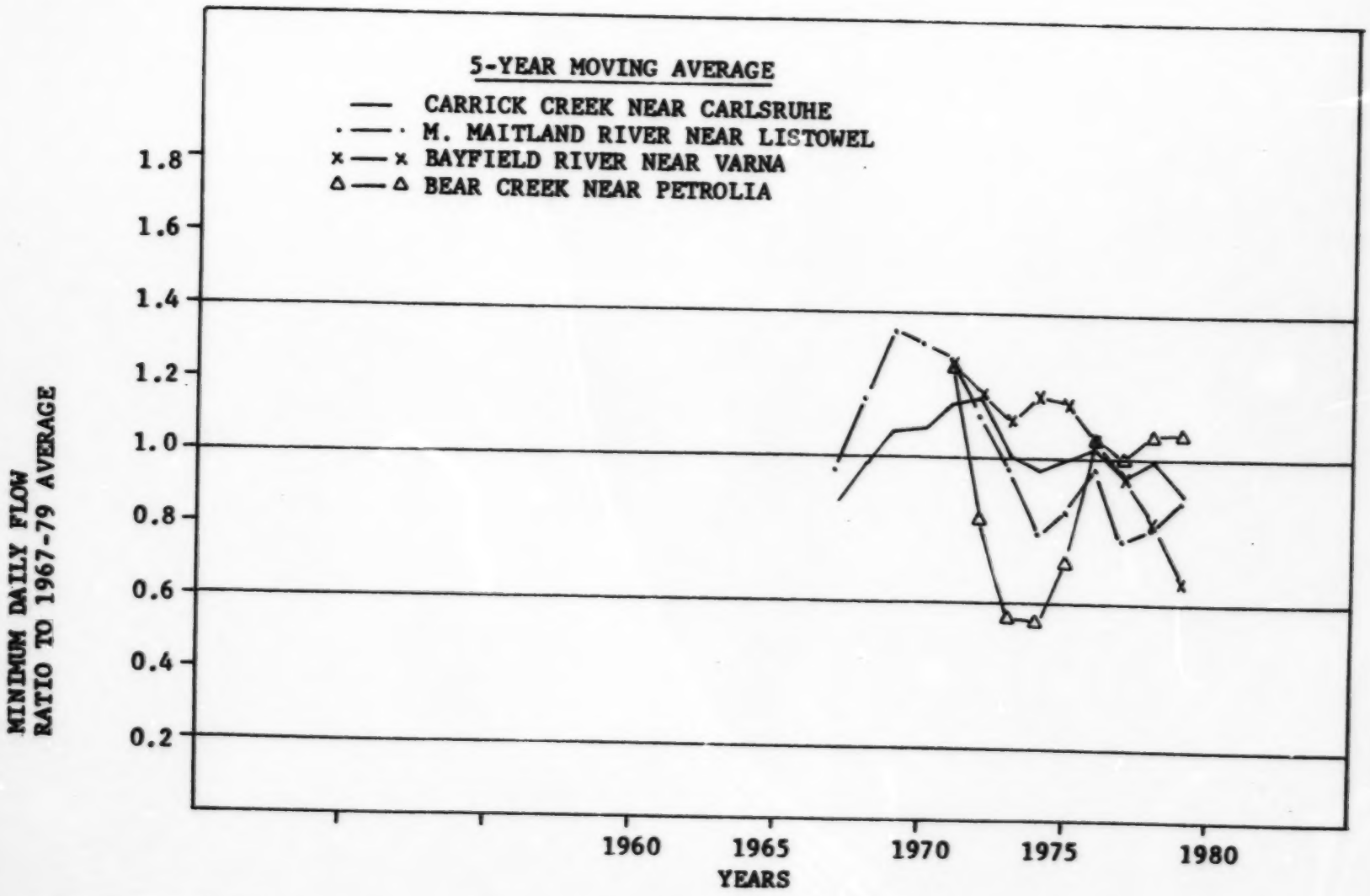

FIGURE 7. VARIATION OF ANNUAL MINIMUM DAILY FLOW AS INDICATED BY SHORT-TERM RECORDS FOR THE PERIOD 1967 to 1979.